Historic, archived document

Do not assume content reflects current scientific knowledge, policies, or practices.

A99.9 F7625U

United States
Department of
Agriculture

Forest Service

Pacific Northwest
Research Station

Research Note
PNW-RN-546
February 2005

Harvesting Morels After Wildfire in Alaska

Tricia L. Wurtz, Amy L. Wiita, Nancy S. Weber, and David Pilz[1]

Abstract

Morels are edible, choice wild mushrooms that sometimes fruit prolifically in the years immediately after an area has been burned by wildfire. Wildfires are common in interior Alaska; an average of 708,700 acres burned each year in interior Alaska between 1961 and 2000, and in major fire years, over 2 million acres burned. We discuss Alaska's boreal forest environment, describe what is known about the ecology of morels that fruit after fire, and report the morel productivity of three recently burned areas in Alaska. In addition, we describe the results of a series of indepth interviews on the commercial harvest of morels in the Pacific Northwest, western Canada, and Alaska, including information on current harvests, the potential for and constraints to development of an Alaskan morel industry, and potential resource management and business development implications.

Keywords: Morel, *Morchella,* Alaska, wildfire, mushrooms, commercial harvest, nontimber forest products, special forest products.

Part 1

Introduction

Mushrooms of the genus *Morchella* are considered among the choicest edible mushrooms in the world. Demand for these fungi is greatest in regions where French cuisine is practiced (Kenney 1996), but they are used increasingly in the regional cuisines of the United States (Weber 1995). Because morels have not yet been farmed successfully on a large scale, the industry is based on the harvest of wild mushrooms.

[1] **Tricia L. Wurtz** is a research ecologist, U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, Boreal Ecology Cooperative Research Unit, Box 756780, University of Alaska Fairbanks, Fairbanks, AK 99775; **Amy L. Wiita** is a research associate, Institute of Social and Economic Research, University of Alaska Anchorage, 3211 Providence Drive, Anchorage, AK 99508; **Nancy S. Weber** is an affiliate professor and **David Pilz** is a faculty research assistant, Department of Forest Science, Oregon State University, 321 Richardson Hall, Corvallis OR 97331-5752.

Morels collected in the U.S. Pacific Northwest are a nontimber forest product of considerable economic significance. In 1992, approximately 3.9 million pounds of wild mushrooms were sold in Oregon, Washington, and Idaho, with 1.3 million of that being morels. An estimated $5.2 million was paid to morel harvesters (Schlosser and Blatner 1995).

Most commercial morel harvesting in North America occurs in the Western United States and Canada, where wildfires can create an ideal fruiting environment in the first years following a fire. Large wildfires are common in interior Alaska, and morels can fruit prolifically in the years following them. Yet there has been little commercial morel harvesting activity in Alaska. The first, and to date only, major influx of commercial morel harvesters to Alaska occurred in 1991, to the area burned in the 1990 Tok River Fire. In this paper, we discuss the constraints on the morel industry in Alaska, including issues related to access, productivity, and markets.

In the summer of 2004, wildfires burned more than 6.7 million acres in interior Alaska (Ipsen 2004); more area burned that year than in any year since record-keeping began in the 1950s. About 20 percent of the burned areas are located along the road system, making them accessible to Alaskans wishing to harvest morels, as well as making them potentially attractive to commercial mushroom pickers from the Lower 48 States and Canada. People in Alaska need information about morels so that they can take advantage of the crops if they occur, either for home use or as a commercial enterprise. Landowners and managers need information about this nontimber forest product in order to plan for and manage the use of this resource on their lands.

This report has two goals: (1) to compile the results of our research over the last three growing seasons on the ecology of postfire morels in interior Alaska, and (2) to discuss our analysis of commercial morel harvesting in Alaska, including the current level of harvest, the potential for future commercial development of a morel industry, and the implications for business development and resource management.

Alaska's Interior

Interior Alaska is the area north of the Alaska Range and south of the Brooks Range, from the Canadian border on the east to as far west as trees are found in western Alaska. It encompasses over 108 million acres. In this boreal forest region, the primary natural disturbance is wildfire. Land in interior Alaska is classified

into one of four fire management categories, with the vast majority of the area designated "limited suppression" (Alaska Wildland Fire Coordination Group 1998). Fires in these areas are monitored but not suppressed unless they threaten to spread to lands where fire protection is desired. Thus, in the majority of the land area of interior Alaska, wildfires are not suppressed.

An average of 708,700 acres burned each year in interior Alaska between 1961 and 2000, and in major fire years, over 2 million acres burned (Kasischke and others, in press). Fifty-five percent of the total area burned between 1961 and 2000 occurred in just six major years. The year 2004 broke all the records, with 780 fires burning more than 6.7 million acres (Ipsen 2004) (fig. 1).

The vast majority of land in Alaska is public land. Major landowners include the federal government (about 60 percent of all the land in Alaska) and the state of

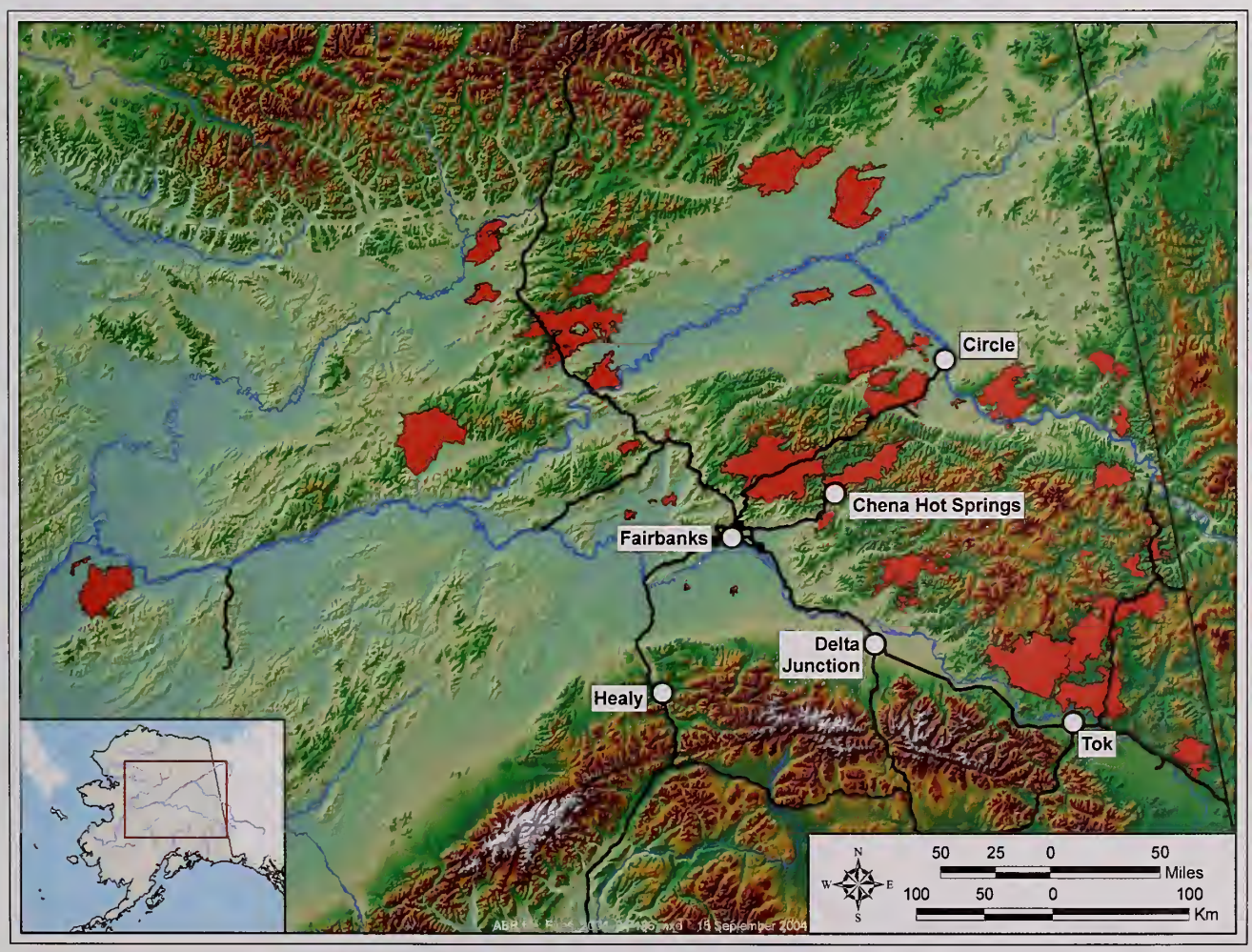


Figure 1—Interior Alaska, with the areas burned in major wildfires during summer 2004 shown in red. Fire perimeters are preliminary as of September 2004 and are courtesy of the Alaska Fire Service.

Alaska (about 25 percent) (Clarke and Angersbach 2001). The major private landowners are a variety of Native corporations, which together own about 10 percent of all the land in Alaska.

Interior Alaska has very few roads. Alaska has only 0.02 miles of road per square mile of land area; for comparison, California has 1.08 miles of road per square mile of land area (Roach 2002). Typically, most land affected by wildfires in Alaska in any given year is not accessible by road. Even when fires occur along the road system, the area that is ultimately burned usually extends far from any existing road (fig. 2). Salvage logging is rarely done after a fire in Alaska, further limiting the access routes that mushroom harvesters might rely on in other regions. Lack of existing road access is one of the main limitations on the use of timber and nontimber forest products in interior Alaska.

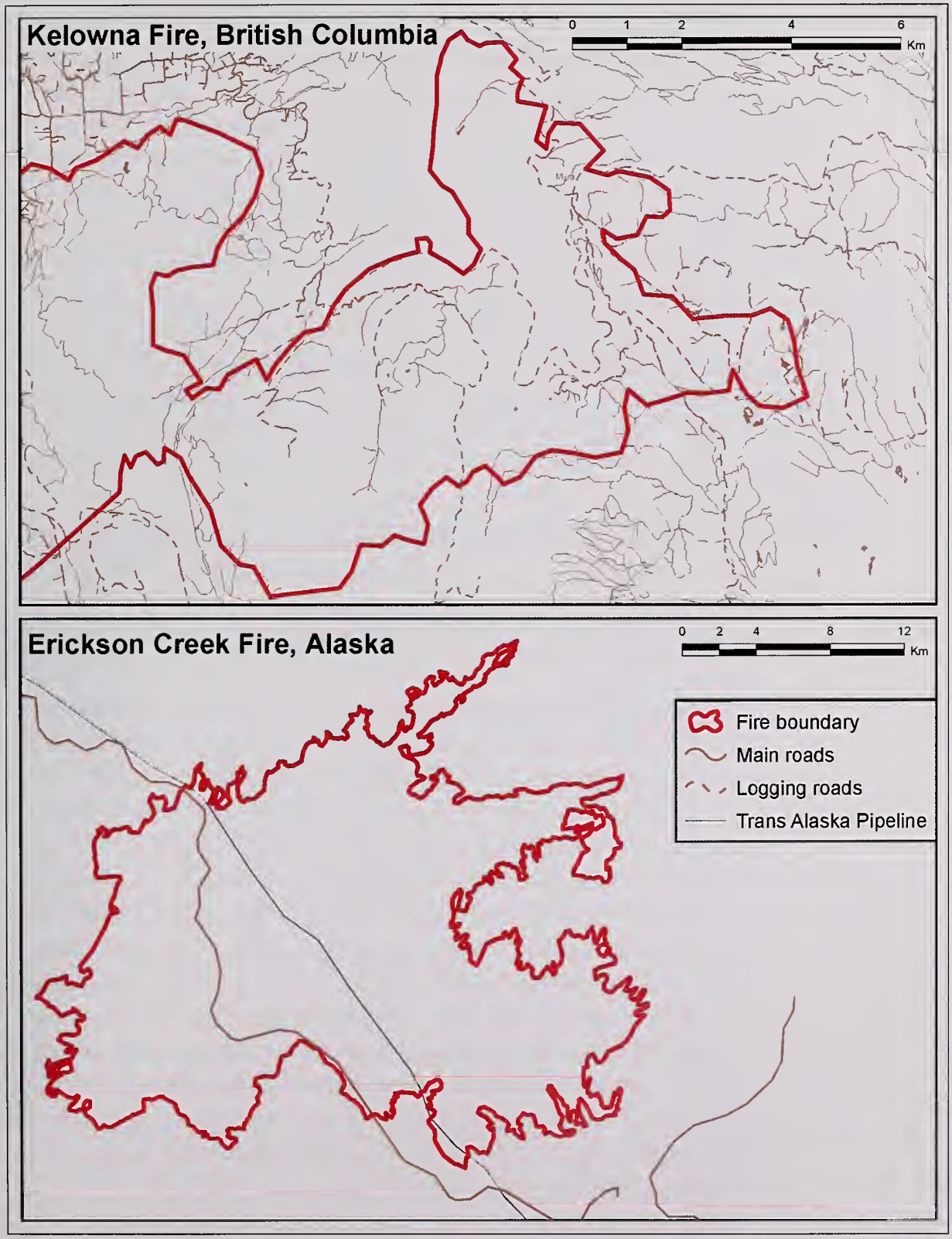
Part II

Morel Ecology

"Natural" Fruiting Versus Fruiting After Disturbance

When morels fruit following a large-scale disturbance, yields are sometimes expressed in tons.

The appearance of fleshy mushrooms is called "fruiting," and the mushrooms themselves are referred to as "fruiting bodies." In the case of morels, two types of fruiting are recognized: the appearance of mushrooms in undisturbed locations (where the mushrooms are sometimes referred to as "naturals"), and fruiting in response to some kind of disturbance. The first type of fruiting can occur in a wide variety of habitats: undisturbed forests, abandoned orchards, lawns, and in sandy soils along streams (Arora 1986, Weber 1995). In such cases, morels can often be found in the same location year after year, although the number of fruiting bodies is generally small. In contrast, when morels fruit following a large-scale disturbance, yields are sometimes expressed in tons (Duchesne and Weber 1993, Moser 1949, Obst and Brown 2000). Disturbance events that can prompt morel fruiting include timber harvest and scarification, insect infestations in the forest overstory, or wildfire (Pilz and others 2004). In these cases, although the number of mushrooms can be large, fruiting typically occurs only the first or second summer after the disturbance. It appears that some *Morchella* species groups, or possible species, fruit in undisturbed habitats and others are likely to be found only after disturbance (Pilz and others 2004).



Matt Macander, ABR Inc.—Environmental Research & Services, Fairbanks

Figure 2—Comparison of the road networks through areas burned in recent wildfires. Top: a portion of the area burned in a 2003 fire southeast of the town of Kelowna, British Columbia. Bottom: the area burned in the 2003 Erickson Creek Fire, about 100 miles north of Fairbanks, Alaska.

Taxonomy

The taxonomy of the genus *Morchella* is confusing and is still the subject of much debate among mycologists. Identifying specimens to species is complicated because fleshy fungi can vary substantially in appearance in response to different microclimates, can change in appearance dramatically as they grow, and are short lived. Consequently, the number of species of the genus *Morchella* that occur in Alaska is still not agreed upon. Recent analyses by O'Donnell and others (2003) suggest there could be as many as 22 species of *Morchella* endemic to North America. Of these, we speculate that five or six species occur in interior Alaska. We refer to these possible species as "putative" species of *Morchella*. For this report, we will not attempt to distinguish among them. In any case, many mushroom pickers use an informal classification system, identifying morels on the basis of color as "blonds," "grays," or "blacks" (McFarlane and others, in press).

Life Cycle

There are several challenges in understanding why mushrooms appear where and when they do. Fungi are difficult to study in natural habitats; they exist for much of their life cycle as delicate mycelia embedded in the substrate, mixed with other species of fungi (Pilz and Molina 2002). The fruiting bodies of the fleshy fungi are ephemeral and might not appear at all for decades. As a consequence, the dynamics of fungal populations in general, and morels in particular, are poorly understood (Volk 1991). There is little well-established information on morel reproduction, spore dispersal, colony establishment, and growth under forest conditions.

A number of investigators have proposed the following life cycle for post-disturbance *Morchella* (Miles and Chang 1997, Volk 1991, Weber 1995). A massive fruiting of morels that follows a wildfire leads to the dispersal of millions of spores. Some settle in the burned area, while others drift into nearby, undisturbed forests. Because morel spores have thin walls and germinate readily under moist conditions (Weber 1995), it is unlikely that they persist in the soil for long periods (Hervey and others 1978, Pilz and others 2004, Schmidt 1983). The spores germinate and produce mycelia, which grow through the soil almost like underground spider webs. At some point, the mycelium begins to form storage organs known as pseudosclerotia, compact clumps of hyphae in which nutrients are stored (Ower and others 1986, Volk 1991, Weber 1995). For reasons that are not understood, the disturbance event then prompts a new fruiting.

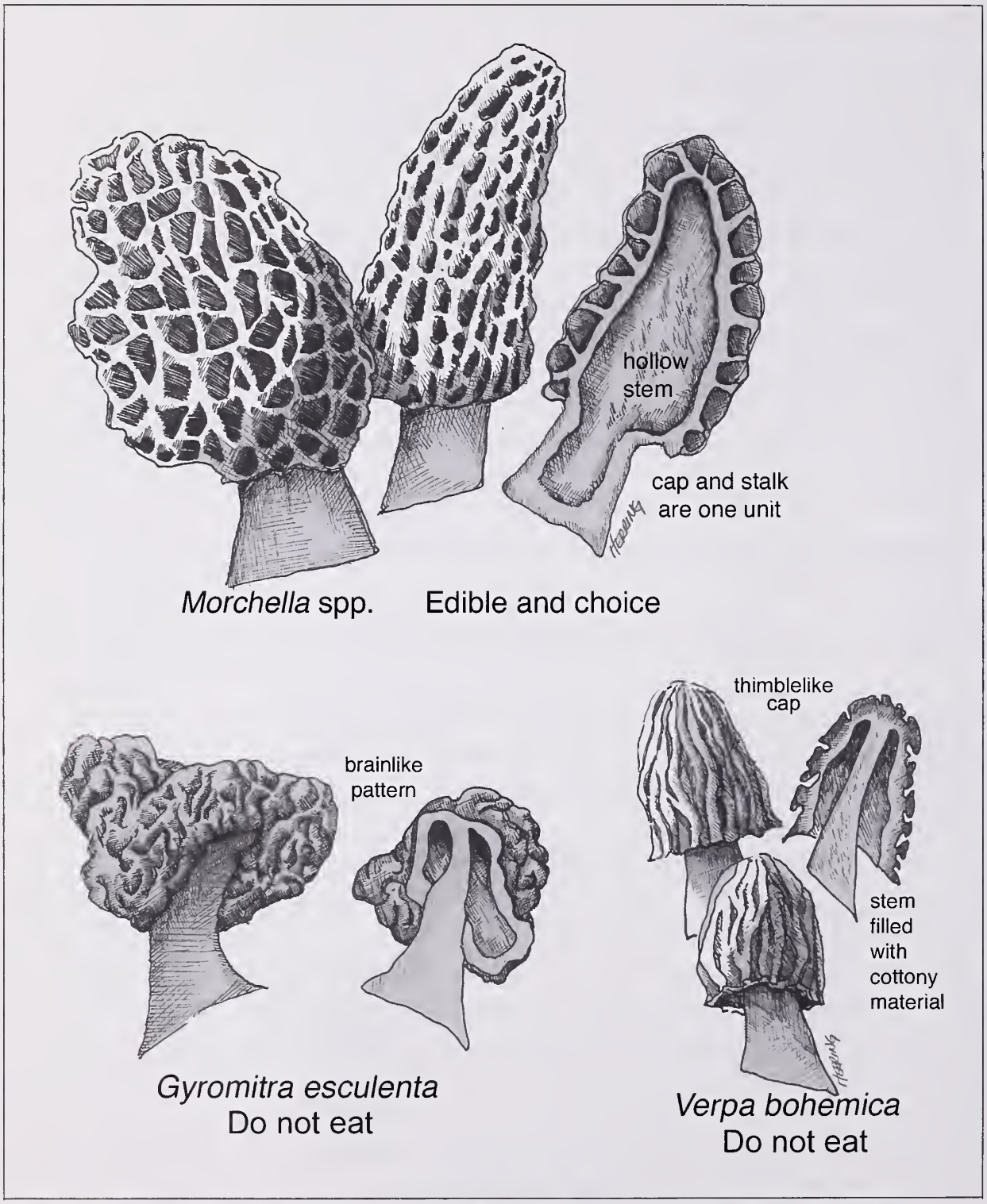
One critical aspect of the life cycle of any organism is its mode of nutrition. Species of the genus *Morchella* were assumed for years to be saprobes, fungi that make their living from dead material, such as leaf litter and dead wood. Recent research has found that some species of *Morchella* could in fact be mycorrhizal, or mycorrhizal some of the time (Buscot and Kottke 1990, Dahlstrom and others 2000, Harbin and Volk 1999, Hobbie and others 2001). Mycorrhizal fungi actually invade the roots of living trees and other plants to establish a mutually beneficial relationship: the fungus collects soil nutrients that occur at low concentrations and exchanges them for photosynthates from the tree. When a fire kills or severely injures the tree, the pseudosclerotia described earlier might function as a backup source of nutrients. The fungus then seeks new food sources and substrates to colonize, and it does this by producing fruiting bodies and releasing millions of spores. Although this topic has been studied for years from a variety of perspectives, only a few pieces of the puzzle have been established conclusively, and most of what we have described above is speculation. A clear understanding of the mode of nutrition of different *Morchella* species will go a long way toward understanding their responses to disturbance.

Distinguishing Among Early Morels, False Morels, and True Morels

The common term "morel" can be used to mean fungi of the genera *Morchella* (the true morels), *Verpa* (the early morels and the thimble morels), and several species of *Gyromitra.* Of the several species of *Gyromitra* that might be encountered in Alaska, two are especially important for morel hunters to learn: *Gyromitra esculenta* ssp. *lato*, the beefsteak false morel, and *G. infula* ssp. *lato*, the elfin saddle. The following paragraph, taken from the book *Mushrooms Demystified*, sums up the major differences in appearance (Arora 1986: 793):

> A *Verpa* looks like a thimble stuck on a finger, i.e. its smooth to wrinkled or pitted cap is attached only to the very top of the stalk so that its sides hang free like a skirt. The true morels (*Morchella*), in contrast, feature a pitted cap that is entirely or partially intergrown with the stalk, while the false morels (*Gyromitra*...) have lobed, or brain-like caps.

It is important to learn to distinguish between these genera (fig. 3). Although verpas and gyromitras are sometimes eaten, **they can be poisonous to some people**. Adverse reactions to these genera do not follow a consistent pattern, so having eaten them in the past, or in a different place, should not be interpreted as evidence of general edibility. We have found *Verpa bohemica* fruiting in undisturbed balsam poplar stands along the Tanana River, and *Gyromitra*



Illustrations by Margaret Herring

Figure 3—Comparison of three genera sometimes referred to as "morels": *Verpa*, *Gyromitra*, and *Morchella*. Verpas and gyromitras are poisonous to some people and should be avoided.

esculenta fruiting in beetle-killed forest on the Kenai Peninsula. Verpas and gyromitras can occur at the same time as *Morchella* in Alaska, and *Gyromitra esculenta* has been found in burned areas. In our experience, however, the true morels (fig. 4) are easy to distinguish from the verpas and gyromitras, with the help of a good mushroom field guide. Most field guides can provide further information on how to distinguish these genera; none of them, however, treat all the species we believe occur in Alaska. The focus of this report, however, is true morels (members of the genus *Morchella*) that fruit following wildfire.

Fruiting Season

High-latitude growing seasons are short, and the fruiting period of morels in interior Alaska is compressed compared with fruiting patterns in the Lower 48 States. In studying morels in interior Alaska for three growing seasons, we have found that some putative species fruit for as little as 2 weeks, and the entire morel fruiting season can last as little as 4 weeks. Sometimes, however, rainfall will provoke several flushes of morels during a single growing season, significantly prolonging the fruiting period (Obst and Brown 2000). In dry years, there is sometimes very limited fruiting or no fruiting at all.

In 1999, a detailed study of the ecology of postfire morels and the economics of harvesting them in a large wildfire area was conducted near Yellowknife, Northwest Territories (NWT) (Obst and Brown 2000). The climate of the Yellowknife area is similar to that of interior Alaska. The primary tree species in the area where the study was conducted were jack pine (*Pinus banksiana* Lamb.), white spruce (*Picea glauca* (Moench) Voss.), paper birch (*Betula papyrifera* Marsh.), and balsam poplar (*Populus balsamifera* L.). The study found that in the NWT morels first began to fruit June 1, and the last morels were found July 30. The season peaked between June 19 and July 14 (Obst and Brown 2000). We have found very similar fruiting seasons in interior Alaska. The 2002-04 morel seasons extended from early June (the earliest we found morels was June 12, but other people reported finding them earlier) to about July 20, peaking during the last few days of June and the first few days of July. On one occasion we found a few morels on August 22.

Several different species, or putative species, can fruit in succession. In the first summer following the burn near Yellowknife, the morels that fruited were identified as *Morchella angusticeps* (in wet habitats in the early part of the growing season), *M. atrotomentosa* (on dry ground, throughout the morel growing season), and *M. esculenta* (found in the transition zone between dry and wet ground, mostly during the later part of the growing season) (Obst and Brown 2000).





Photos by Trish Wurtz





Figure 4—True morels (*Morchella* spp.) that fruit after fire in interior Alaska differ widely in appearance. Arora (1986) calls them "perplexingly polymorphic." These morels were photographed the same day in the Erickson Creek burn area, north of Fairbanks, Alaska. The white ring is 4 inches in diameter.



The lifespan of individual morel fruiting bodies in burned areas depends on local weather conditions and insect populations. The ideal conditions for morel fruiting in interior Alaska would seem to be moist soils coupled with overcast days of moderate temperature. Cool, overcast weather will allow mushrooms to continue growing longer than will hot, dry weather. Although rainfall can prompt additional fruiting by increasing soil moisture and relative humidity, rain can also damage standing mushrooms and speed their decay. If a hot, dry spell begins after the mushrooms have emerged, it can effectively dry them "on the stalk." In our experience, the stalks of such dried mushrooms become brittle, and within days the mushrooms break off, fall to the forest floor, and begin to decompose.

We have observed at least two species of insects laying eggs on morels in interior Alaska. The larvae that hatch from the eggs use the mushroom as their food source and can quickly destroy it. The extent to which we've found morels to be infested with insects has varied greatly with the year and the site. One year nearly half of the mushrooms we picked were heavily infested with larvae of insects from either the Mycetophilidae or Sciaridae families (Kruse 2004). We were not able to determine the species. In other years, we found no larvae or other insects in the morels we harvested.

Whether the issue is insect infestation, rainy weather, or hot, dry weather, in our experience the amount of time that individual morels remain in good, "pickable" condition is short. In some years, there can be simply too many mushrooms to harvest and preserve in a short time. If fruiting is abundant, harvesters should be prepared to work long hours to take advantage of the available mushrooms during the short fruiting period.

If fruiting is abundant, harvesters should be prepared to work long hours to take advantage of the available mushrooms during the short fruiting period.

Productivity

At both the stand and landscape levels, wildfires produce a mosaic of conditions that is largely attributable to forest type and fuel moisture content during the fire. Burn severity (a measure of how extensively the organic layer is consumed) influences the exposure of mineral soil and nutrient release (Viereck 1973, Viereck and Schandelmeier 1980). Burn severity also appears to influence the likelihood of morel fruiting. In burned, high-elevation *Picea/Abies* forests in Montana and Idaho, McFarlane and others (in press) found morels fruiting predominantly in areas of moderate fire intensity, as indicated by a layer of dead conifer needles on top of the fire ash. In our experience in interior Alaska, morels are most likely to be found in moderately to severely burned areas, near the bases of trees. Over the last three growing seasons, we have found morels fruiting among burned white spruce, black spruce (*P. mariana* (Mill.) B.S.P.), and paper birch trees, on a variety of site types.

Only a few investigators have attempted to quantify the productivity of burned areas for morels. In the study conducted in the Northwest Territories, postburn morel productivity was estimated at about 9 pounds per acre in the drier, higher elevation portion of the study site (Obst and Brown 2000). A portion of the area burned in that fire was lower elevation, with wetter soils that had been forested with black spruce, larch (*Larix laricina* (Du Roi) K. Koch), birch, and willow (*Salix* spp.). Fewer morels were found in the lower lying spruce-and-larch forest type. In northeastern Oregon, Pilz and others (2004) worked in wildfire areas that had supported mixtures of grand fir (*Abies grandis* (Dougl. ex D. Don) Lindl.), Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco), lodgepole pine (*Pinus contorta* Dougl. ex Loud.), western larch (*Larix occidentalis* Nutt.), and ponderosa pine (*Pinus ponderosa* Dougl. ex Laws.). They used a strip-plot sampling system and found morel productivities of 0.5 to 8.1 lbs per acre in the first 2 years after fire.

Although stories of large postfire morel crops in interior Alaska are common, few data are available. Over the past three growing seasons, we have found that areas of abundant morel fruiting were widely scattered and difficult to predict. In 2002 and 2003, we documented the productivity of three burned areas near Fairbanks by using the strip-plot sampling methods of Pilz and others (2004). We felt that the method of Pilz and others gave a good representation of the overall morel productivity of those areas and those growing seasons (table 1). The sites supported forest types common in interior Alaska:

- Survey Line Fire. This site was located on the south bank of the Tanana River, southwest of Fairbanks. Our strip plots were located in areas that had supported productive riparian white spruce forest, with an understory of alders (*Alnus tenuifolia* Nutt.), bunchberry (*Cornus canadensis* L.), and feathermosses. Morels were relatively abundant in our plots that year.
- West Fork Fire. This site was about a mile from the west fork of the Chena River, near the end of Chena Hot Springs Road. The strip plots were located on a gentle south-aspect slope that had supported unproductive black spruce forest and cotton grass (*Eriophorum vaginatum* L.), and on a steeper south-facing slope that had supported paper birch and aspen (*Populus tremuloides* Michx.) forest. We found virtually no morels in our plots, and very few were found in any part of the West Fork Fire area, perhaps owing to unusually dry weather in May and early June that year.
- Livengood Fire. Our plots were located on a gentle south slope. Before the fire, one area had supported dense, unproductive black spruce forest, and a second area had a mixture of white spruce, black spruce, and birch. The few morels we found at this site that year were located in this mixed forest.

Table 1—Morel productivity of several burned areas in Oregon, the Northwest Territories, and Alaska

General location	Lat. and long.	Name of fire	Year of fire	Year of morel sampling	Mean number/ac	Mean lbs/ac (fresh weight)	Reference/ notes
Malheur National Forest	N44.07° W118.6°	Summit	1994	1995	127	0.58	Pilz and others 2004
Malheur National Forest	N44.07° W118.6°	Summit	1994	1996	131	5.09	Pilz and others 2004
Wallowa-Whitman National Forest	N45.04° W118.5°	Tower	1994	1995	1,761	3.39	Pilz and others 2004
Wallowa-Whitman National Forest	N45.04° W118.5°	Tower	1994	1996	117	1.98	Pilz and others 2004
Wallowa-Whitman National Forest	N45.08° W118.5°	Tower	1994	1995	1,194	3.70	Pilz and others 2004
Wallowa-Whitman National Forest	N45.08° W118.5°	Tower	1994	1996	182	8.10	Pilz and others 2004
Yellowknife, NWT	N62.55° W113.35°	Tibbitt Lake	1998	1999	140-940	8.92	Obst and Brown (2000); these values were estimates
Southwest of Fairbanks, AK	N64.65° W148.3°	Survey Line	2001	2002	398	5.86	Used same sampling method as Pilz and others (2004)
Northeast of Fairbanks, AK	N65.05° W146.2°	West Fork	2002	2003	4	.02	Used same sampling method as Pilz and others (2004)
North of Fairbanks, AK	N65.38° W148.91°	Tolovana Hot Springs	2002	2003	91	2.34	Used same sampling method as Pilz and others (2004)

Our morel productivity values for interior Alaska are similar to values from the Northwest Territories and Oregon, both in terms of number of mushrooms and their fresh weight per unit area (table 1). Although some commercial mushroom harvesters believe that morels fruit less reliably in Alaska than they do in the Yukon or in British Columbia, data on productivity in different years and in different places are still too limited to examine this assertion.

The Role of Precipitation

Although the optimal amount of precipitation or specific soil moisture requirements for morel fruiting are not known, the productivity of fleshy mushrooms in general is closely related to rainfall (Arora 1986, Carrier and Krebs 2002). In the summer of 2004, we found more morels growing in the Erickson Creek Fire area (which had burned in June 2003) than we had found in any of the three previous burns we studied. We found morels on a steep south-facing slope as well as on a nearly level bench; both were sites that had supported black spruce and birch. We did not use the strip-plot sampling method to quantify the productivity of that fire, and no weather records are available for the exact area of the Erickson Creek burn. However, in Fairbanks, 100 miles to the south, total precipitation in May 2004 was 2 inches, more than three times the long-term mean of 0.6 inches. The unusually rainy May in 2004 probably contributed to the abundant morel fruiting we found at Erickson Creek a month later.

An Indicator Species?

The cup-fungus *Geopyxis carbonaria* (fig. 5) is common on burned sites in interior Alaska. Based on their work in the Northwest Territories, Obst and Brown (2000) suggest that its presence might be an indication of imminent morel fruiting. In interior Alaska, we have found *Geopyxis* to be far more common than *Morchella*. Many places where *Geopyxis* fruited prolifically in early June had no evidence of morel fruiting at any point during the rest of that summer.



Photo by Trish Wurtz

Figure 5—The cup-fungus (*Geopyxis carbonaria*) often fruits prolifically after wildfires and Obst and Brown (2000) considered it to be an indicator of imminent morel fruiting in the NWT. Experience in Alaska has not supported this.

Part III

Interviews and Market Analysis

Methods

Information and data on the personal or commercial harvest and consumption of morels are limited for Alaska, and more generally worldwide. We conducted key-informant semistructured interviews with 40 people from the morel mushroom industry, the food industry, universities, and land management agencies in the United States and Canada. Interview subjects were identified in the course of the literature review and by other key informants. Four people interviewed were from universities, 16 from state or federal land management agencies, 10 from the food industry, 2 from research institutes, 1 from a consulting firm, 6 who were buyers or harvesters in the wild mushroom industry, and 1 from an Alaska Native corporation. Informants provided general and specific data on the morel mushroom industry in Alaska and other locations, on regulation and permitting practices and management implications, industry potential and constraints, business and marketing aspects of the morel industry, market information, and suggestions for additional key informants.

It was difficult to find morel harvesters and buyers in Alaska. We interviewed only one Alaskan who did harvesting, buying, and selling. Most of the buyers we contacted were from the Pacific Northwest. Some key informants provided conflicting information about the potential for an Alaska morel industry.

Results and Discussion

Morel harvesting in the Pacific Northwest—

In the Pacific Northwest, the wild mushroom harvesting industry consists of harvesters, buyers, processors, and brokers. Harvesters, sometimes referred to as pickers, locate and pick mushrooms. Buyers, often associated with a processor, purchase mushrooms from harvesters, usually in the field near harvest areas. Processors handle, clean, pack, and ship the mushrooms and provide cash and field prices to buyers. Brokers market the processed mushrooms around the world (Pilz and Molina 1996).

Morels are harvested by cutting the mushrooms at the stem. The harvested mushrooms are carried in containers that allow air circulation, such as buckets with holes in them, to maintain the quality of the mushrooms after harvesting. Fresh morels are brought to buying stations for sale to buyers or can be dried in the field or home. Both harvesters and processors dry morels for future sale.

Field drying morels can be as simple as air drying or as complex as using drying shacks with dryers powered by generators. Morels are laid out in a single layer so that air can circulate around the mushrooms. Drying shacks usually include racks to spread mushrooms on and dryers to heat, dehumidify, and circulate the air around the mushrooms. Morels should be dried until crisp, like a potato chip (Weber 1995). Once the morels are dried they must be packaged to prevent rehydration. This is sometimes accomplished with vacuum packaging.

Schlosser and Blatner (1995) conducted a survey of the wild mushroom industry in Washington, Oregon, and Idaho. They estimated that 1,325,827 pounds of morels were harvested during 1992 with $5,222,237 paid to harvesters. Oregon supplied 68 percent of this harvest. Schlosser and Blatner found that the primary market for morels was the Western United States, but mushrooms may have been shipped overseas, making the final point of sale unknown. Parks and Schmitt (1997) found that 40 percent of the morels harvested in the Blue Mountains region of Oregon were sold to Asian and European markets, and 42 percent were sold in the Western United States. Most edible wild mushrooms exported from the United States to the European community come from the Pacific Northwest, and the majority are shipped from Seattle (Jones and others 2002).

Our interviews indicated that over the last few growing seasons in the Pacific Northwest, prices paid to harvesters for fresh morels generally averaged $4 to $6 per pound. In 1992, the average price paid by processors in Oregon, Washington, and Idaho for morels was $4.14 per pound (Schlosser and Blatner 1995). In 1996, the mean price for morels harvested in Oregon, Washington, and Idaho was $5.60 per pound (Blatner and Alexander 1998). In April 2004, morels were being purchased near Kelowna, British Columbia, for just over $10 per pound,[2] but as the season progressed and more people began to harvest mushrooms, the price dropped quickly to approximately $3.35 (Moorhouse 2004).

Morel harvesting in Canada—

Morels are widely harvested in the Yukon and NWT of Canada, which are similar in climate and remoteness to interior Alaska. The industry is well established in the Yukon and struggling in the NWT. Obst and Brown (2000) documented the economics of a morel harvesting pilot project conducted near Yellowknife, NWT, in 1999. The report is generally optimistic and encourages the development of a morel industry in the NWT.

In that pilot project, all harvested or purchased morels were pooled, labor was shared, and profits were split after the expenses and start-up loans were repaid. Shares in the organization were allotted to a buyer, his crew of five pickers from southern Canada (who had traveled to Yellowknife for this effort), and each of the organizers of the project. Additional morels were purchased from local pickers at a set price of $3.70 per pound of fresh morels (Obst and Brown 2000). Most of the mushrooms picked as part of this pilot project were dried in the field by using a two-step, generator-powered method.

The mushrooms were then sold to international retailers. The price paid by retailers for dried morels in June 1999 ranged from $64 to $102 per pound, then jumped to $188 per pound at the end of July and to $323 per pound by September 1999. As part of that study, 10 commercial buyers from Europe, Canada, and the United States visited the NWT to assess Canadian morel production first hand. They found the quality of NWT morels to be excellent, and requested 33,000 to 66,000 pounds of dried NWT morels per year (Obst and Brown 2000). Since that study was conducted in 1999, however, the morel industry in the NWT has not flourished and this demand has not been met. Reasons include lack of access to burned areas and high transportation costs. A key informant indicated "the [NWT] industry lost money even in good production years."

[2] All dollar values reported in this document are in U.S. currency.

The Yukon enjoys more consistent morel harvests, a developed road infrastructure, and an established buying network seated in Vancouver, British Columbia, that jointly have created a viable industry. Wills (2002) found that "in a good year, approximately 225 000 kilograms [500,000 pounds] of morels are harvested in British Columbia (BC) and the Yukon, but in a bad year this figure may fall to the range of 10 000 to 20 000 kilograms [20,000 to 45,000 pounds]." (We interpreted this to refer to fresh weights.) Seventy-five to eighty percent of all morels exported from British Columbia come from the Yukon because of fire suppression in British Columbia (Wills 2002). Most buyers and pickers in the Yukon, however, are from British Columbia.

A consultant we interviewed stated that although there is a large North American wild mushroom market, he estimated that Oregon, Washington, British Columbia, the Yukon, and Alaska jointly supply less than 10 percent of the world's wild mushrooms.

World market—

Wild mushroom prices are among the most volatile of nontimber forest products. Prices can vary on a daily basis depending on markets. Kenney (1996) noted that "the best word to describe the global market dynamic for morel volume might be *erratic*." He continued, "There are no comprehensive statistics kept by nation on morels…distributors raise the price when supplies are low and the market drives the price lower when harvests are bountiful." Blatner and Alexander (1998) equate varying mushroom prices to those of wheat—news of a good crop from overseas can adversely affect prices in the Pacific Northwest and timing of large shipments entering a specific market will affect local prices. Markets are also sensitive to the number of wildfires that occur.

There is significant competition for the Pacific Northwest industry from other countries such as China, Russia, India, and eastern European nations, where lower labor costs allow them to sell morels at lower prices than are typical in the United States. "The opening of trade with eastern bloc countries gave the European Union a supply…of morels…that are closer, with lower transportation costs and lower wage expectations than the U.S. market" (Jones and others 2002).

One buyer we interviewed stated that the world market does not need Pacific Northwest (PNW) morels. The buyer stated that good-quality dried morels from the PNW generally sell for $125 to $175 per pound with poor-quality dried morels selling for approximately $50 per pound. In contrast, the buyer stated that India is

selling good-quality dried morels for only $25 per pound. According to this buyer, the industry in the PNW is declining because of increased competition and adverse weather. Other people we interviewed maintained that the United States still has a major role in the morel industry.

Fresh versus dried—

According to our interviews, fresh morels lose 10 to 15 percent of their moisture content in the first 24 hours after harvest. Eighteen to twenty percent moisture loss is average from harvest to final point of sale. Moisture loss is a loss in revenue for fresh morel sales with payment determined by weight at the final point of sale. According to our key informants, fresh morels should ideally arrive at the final point of sale, including European markets, within 24 hours of harvest.

Although fresh morels command a high price, they have a very limited shelf life, leading most commercial morel harvesters to dry their mushrooms. Dried morels are marketed on the Internet and through brokers. Eight to ten pounds of fresh morels are needed to make one pound of dried. Assuming an average price per pound of $5 fresh and $125 dry and a wet-to-dry weight ratio of 10 to 1, dried morel prices are, on average, approximately 2.5 times those of fresh morels.

Eight to ten pounds of fresh morels are needed to make one pound of dried.

Harvester income—

Most harvesters do not make a great deal of money harvesting morels. Given the world market for the product, large companies and big buyers have significant control over market prices. A key informant noted that "circuit pickers [people who follow the mushroom harvests from place to place, picking a variety of species] can make more money pumping gas, [but it is] more than just about the money, it's a way of life, freedom, [a] love of the woods." Another person interviewed said that he only makes $30,000 in a good year harvesting a variety of different types of mushrooms.

The Alaskan Outlook

Alaska Natives did not traditionally eat wild mushrooms. There was a strong taboo against eating mushrooms among the Iñupiaq people of northern Alaska; mushrooms were considered something to be avoided (Jones 1983). A key informant indicated that fungi are not generally mentioned by Alaska Natives in subsistence surveys conducted by the state of Alaska. He noted that they are not preserved and are not written about in stories.

Over 300,000 pounds of mushrooms were purchased by nine different buyers who traveled to Tok from the Pacific Northwest and Canada.

Past commercial harvests—

The 90,000-acre 1990 Tok River Fire led to the first, and to date, only major influx of commercial pickers to Alaska. The harvest occurred primarily on lands owned by the Tetlin Native Corporation. From a December 1991 memorandum written by Tok Area Forester Dick Malchow (1991):

> It is estimated that over 300,000 pounds of mushrooms were purchased by nine different buyers who traveled to Tok from the Pacific Northwest and Canada. These buyers were paying from $2.00 to $3.00 per pound green weight, of which Tetlin Native Corporation was charging the buyers $0.25 per pound for royalties. Up to 150 people participated in the harvest, many of whom were professional pickers from the South 48 and Canada. This included a group of 30 … who camped out for a 60-day period along the Tok and Tetlin Rivers.
>
> …Garbage accumulated, collecting buckets were left in the field, the navigability of the Tok River was blocked by a make shift bridge, and erosion was accelerated on steep slopes due to the misuse of ATVs.
>
> …These buyers came up to Alaska for the first time this year, not knowing what to expect. If they had been better organized, they felt mushroom production from the Tok fire could have exceeded one million pounds. The Tetlin Native Corporation estimated that this would have enabled them to collect over $500,000 in royalties…

We interviewed a Tok resident who participated in that harvest, using his own four-wheeler and trailer. He said that the summer of 1991 was rainy, that mushrooms popped up again and again on some sites, and that the mushroom-picking season lasted more than 2 months. Initially the outside buyers offered $2 per pound fresh weight, but he did some research on the prices that were being paid in Oregon and got the pickers to band together until the price was raised to $3 and then to $4 a pound. He reported that nearly everyone in Tok participated in the harvest to some extent, but only 10 to 15 people were really serious. He referred to the different types of morels he picked as blonds, blacks, and grays, and said that the largest blond and gray morels were shipped fresh to San Francisco.

One buyer had so many mushrooms that he rented a Tok airplane hangar in which to dry them. On his best days, our informant was able to pick between 200 and 300 pounds of mushrooms. The buyers always paid him in cash, and because no records were kept on these transactions, the Tetlin Native Corporation had a hard time collecting royalties from the buyers. He personally earned $15,000

picking mushrooms that summer and said that several people in Tok earned more picking mushrooms than they had working on fire-fighting crews the previous year. He also mentioned tensions over picking areas that developed between the pickers from outside Alaska and the Tok residents.

We spoke with another harvester who has picked more recently burned areas in Delta Junction, Tok, and Chicken, Alaska. Each location had different degrees of productivity and very few harvesters. The harvester told us he taught several miners, who were unable to mine due to weather conditions, to pick morels on the 1999 Chicken Fire. Very few people picked the 1999 Delta Junction Fire until the end of the season when, even then, only about 50 people were picking. The harvester we spoke with was able to ship fresh morels to San Francisco from the Delta Junction burn, by renting local refrigerator space to store the fresh mushrooms and shipping them periodically from Fairbanks. Prices were high enough and the harvest area was close enough to Fairbanks to make this feasible.

Markets in Alaska—

At least nine restaurants in Alaska use fresh morels in their cuisine seasonally. Restaurants purchase fresh morels from both local and out-of-state suppliers. Most Fairbanks restaurants that use morels purchase them from large food suppliers in the Lower 48 States. One Fairbanks restaurant indicated they would purchase morels from a local supplier if they were available. One in-state supplier indicated he sells both Alaskan-harvested morels as well as morels harvested outside the state. This would suggest that Alaska demand for morels currently exceeds the quantity harvested within the state.

Dried morels can be stored in anticipation of higher prices and can be marketed directly or over the Internet. We could find no information on the shelf life of dried morels, but Weber (1995) describes several ways that they can deteriorate in storage. Obst and Brown (2000) suggest that their two-stage drying method would preserve morels for at least 2 to 3 years.

Licensing requirements—

No licenses or authorizations are required to either buy or sell wild mushrooms as a food product in Alaska. Key informants noted that harvesters and restaurants have, for the most part, successfully self-monitored the sale of wild mushrooms to date.

Major constraints on an Alaskan industry—

The most significant constraint on a morel industry in Alaska could be reliable crop production. Although fruiting can be abundant in some years, in other years there is

virtually no crop at all. Alaskans who wish to harvest morels commercially will need to be prepared to take advantage of good crops when they occur and rely on other sources of income when they do not.

Such opportunistic picking might be the most likely way for rural Alaskans to participate in a morel harvest (Arora 2001). The morel season in Alaska is a time when most people are already engaged in subsistence or recreational activities. People could find it difficult to stop everything they are doing to harvest a massive fruiting of morels that has to be harvested and processed all at once. Harvesting a burn area is generally hot, dirty, physically taxing work.

Other constraints in Alaska are the lack of road access, the limited local market, and lack of experience in the morel industry. In his study of developing a morel industry in the Yukon Territory, Kenney (1996) found a lack of knowledge about the international industry and distance from European markets to be the two largest constraints.

Potential for Industry Growth in Alaska

Alaska's morel industry has potential but caution is advised. The 1990 Tok Fire experience indicates that if a fire is large and accessible, fruiting is prolific, and market prices are sufficient, people will come from around the state, the Lower 48 States, and Canada to harvest mushrooms in Alaska.

The potential for an Alaska morel mushroom industry will be partially determined by the degree of innovative marketing employed in the industry. Local cooperative extension offices, small-business development offices, and research institutes could facilitate the dissemination of knowledge needed for the marketing, processing, handling, and other business skills necessary to develop a morel business.

Key informants agree that a business in the morel mushroom industry in Alaska must be flexible and accommodate unpredictable morel fruitings, employ creative marketing, have knowledge of morel markets and direct-marketing techniques, and have the ability to splice a morel business with other business ventures. One informant in interior Alaska used his job as a helicopter pilot to scout burned areas for morels as he flew over on other business. The short stature of the burned black spruce forest allowed him to fly low enough to see patches of mushrooms from the air, and he would return later to pick them for personal use. It is unlikely, however, that the price of morels would support the use of helicopters to locate patches for commercial harvesters.

In Saskatchewan, business in the wild mushroom industry can be lucrative, but yields vary widely depending on weather. "Harvesters have to maintain a portfolio of activities and choose the product which gives the greatest potential return in a given year" (Saskatchewan Environmental Society, n.d.). The government of Saskatchewan actively encourages wild mushroom harvesting and promotes the involvement of First Nation and local communities. The industry is promoted through the media, government subsidies, and small-business development programs. A Saskatchewan Trade and Export Partnership (STEP) February 20, 2004, news release states "cooperative relationships between Saskatchewan Agriculture, Food and Rural Revitalization, Agriculture Canada and STEP provide Saskatchewan organic producers and exporters with all the tools to successfully market their products in Europe and beyond."

Organic or Alaska-Native-harvested products could have potential in Europe where informants said that organic and Native American products are preferred.

Niche marketing of dried morels—
Another opportunity lies in the small-scale production of value-added dried morels targeted at niche markets such as the Alaska tourist or organic markets. Key informants indicated that organic or Alaska-Native-harvested products could have potential in Europe where informants said that organic and Native American products are preferred. Some questions to ask in evaluating the potential of an Alaska morel industry: What unique characteristics exist in Alaska that do not exist elsewhere? How could a business leverage these characteristics in an Alaska morel industry? The answer could lie in our tourists, wild foods, and natural specialty products. Alaska's established bush pilot, wild food, and tourist industries might in fact be the combination of factors key to successful morel ventures. Pilz and others (N.d.) provide a thorough analysis of marketing nontimber forest products from Alaska.

Potential Implications for Business Development

The wild mushroom industry is highly dependent on an individual's creativity, ingenuity, and fortitude to make a business viable. Records on production and processing from other places are generally restricted to established processors and shippers. The mushroom business has largely been an "underground" business dealing in cash (Parks and Schmitt 1997). This lack of information and the cash-based economy make entering the industry difficult.

Buying and marketing morels requires an extensive knowledge of morel markets, business savvy, cash to purchase morels, and capital investment in both time and money. Harvesting is difficult, intense labor with generally low returns on the time and effort invested.

Businesses would likely need to develop creative marketing plans to find niche morel markets best suited for the industry in Alaska. Drying the product would allow harvesters to focus all their energies on picking during the short window that mushrooms are available. Local communities and businesses could consider developing cooperatives for the sale of organic or Alaska Native products in the European market. Harvesters in Saskatchewan have sought out their own markets and developed cottage industries to increase the value of their product and to avoid dealing with large-scale brokers (Saskatchewan Environmental Society, n.d.).

Schnepf (1992) presents a summary of the production, marketing, and management needs to be considered by businesses wanting to become involved in the special forest products (SFP) industry. Key issues and questions relating to why a business may want to enter the SFP industry, market considerations, harvest sites, harvest feasibility, and pricing are briefly discussed. The Saskatchewan Environmental Society (n.d.) stresses the need for businesses to understand marketplace standards, packaging, pricing, distribution, and, most important, how to run an effective business.

Potential Implications for Resource Management and Policy

It is a challenging proposition to regulate and manage a resource that is dispersed on the landscape and based on largely unpredictable wildfire events and weather patterns. Adding to the challenge is the fact that the specific location of the resource is not known in advance and once it has appeared it lasts only a few weeks. In the Pacific Northwest, having numerous morel harvesters working in small areas has led to user group conflict, as well as regulatory needs for camping, sanitation, and personal safety. As a result, the regulations and policies that govern morel harvesting in the Pacific Northwest have been implemented primarily to manage the harvesters and to prevent picking in specified areas.

Most existing regulations and permit systems for Alaska's public lands were developed with other resources in mind, and Alaskan land managers have only begun to address the issues of nontimber forest products on their lands. Some questions to consider when developing regulations: What is the purpose of management? Do the resources, people, or lands need management? Whom do regulations and permits affect, and how? Local input from Alaska Native and non-Native people in the industry is important to inform the management process in Alaska.

Several agencies in Alaska are now in the process of developing policies for the use of nontimber forest products. We received some conflicting policy information from agency personnel. Shortly before publication, personnel for the Alaska

Department of Natural Resources (DNR) and the U.S. Department of the Interior, Bureau of Land Management (BLM), two of the primary land management agencies in interior Alaska, reported the following plans for managing mushroom harvesting:

- The Alaska DNR charges $100 for an annual land use permit for the commercial harvest of mushrooms. In addition, a fee of $0.20 per pound, which is 5 percent of the current average fresh price per pound, is charged for mushrooms. This fee for harvesting on DNR lands was developed in comparison to other agencies as well as the private sector and formalized in the Alaska Administrative Code (11 AAC 05.010(e)(22)(I)). According to the DNR, a higher fee might be required if the director determines that the location or nature of the use makes a higher fee appropriate to ensure a reasonable return to the state. The department would leave it to the harvesters to assess and remit the per pound fee at the end of their harvesting efforts. This system was only recently developed and has yet to be tested.
- Currently, the personal use of wild mushrooms from BLM lands in interior Alaska does not require a permit. For commercial use, the agency must determine the fair market value of the resource in question. It is likely the BLM would use market values similar to those set by the state of Alaska: $0.20 per pound, with a minimum permit price. One option available to BLM managers is a programmatic environmental assessment, a process that assesses the potential adverse impacts on public lands of the proposed activity on a large scale and develops a plan to mitigate those impacts. A programmatic environmental assessment can be done before the mushroom season begins, and can allow a manager to identify the lands suited for harvesting, based on best management practices and input from resource specialists. Similarly, commercial harvesting would likely be excluded from some areas, such as areas of critical environmental concern and wild and scenic areas. Permits could be speedily issued under the terms of the assessment and could allow pickers exclusive rights to particular areas until they meet the pound or day limits.

Permit fees are often developed when market prices are high and harvesting is intense, and generally are not altered with changing market conditions. Permits that encourage stewardship of the land and resources and provide incentives for data collection might be better alternatives to the standard use permit. Foraging permits modeled after hunting and fishing licenses are another practical, cost-effective alternative.

The government of the Yukon has produced a brochure and an information guide about harvesting morels (Indian and Northern Affairs Canada 1999). The guide gives field identification tips, gives suggestions on finding areas suitable for picking, includes an equipment checklist for camping and hiking in remote areas, reviews the regulations relating to permits, and gives suggestions on handling, transporting, and drying morels. To respond to numerous inquiries from interested harvesters, the government of the Yukon also maintains a section of its Web site, called *Historical fires,* primarily for mushroom pickers. It is posted in January of each year, and provides downloadable .pdf maps for each major fire, including road access, burn perimeters, and topography (Milne 2004).

Concerns about the sustainability of harvesting edible fungi have arisen owing to intense harvest pressure on some species in the Pacific Northwest and in Europe. In Europe, the productivity of many species of edible fungi is declining (Pilz and Molina 2002). Most of these concerns, however, involve species of fungi that fruit in the same place year after year. Because morels fruit prolifically for only a year or two after disturbance, they present a different set of questions. So little definitive information exists on the ecology of the various *Morchella* species that what constitutes the sustainability of this genus has yet to be clearly articulated. Does sustainability mean that it will fruit in the same location following the next disturbance that occurs there, even if it is 200 years hence? Or does sustainability mean that the number of healthy *Morchella* mycelia that exist in a landscape at any given time remains approximately constant? Some authors draw an analogy between picking morels and picking apples from a tree; the tree is not damaged even when all the apples are picked (Molina and others 1993). The dominant opinion at this time is that morel harvesting is not harmful to the fungus in the short term, but a better understanding of the ecology of postdisturbance *Morchella* species is needed.

Part IV

Predictions for 2005

Morel Fruiting

Although Alaska appears poised to have a bumper crop of morels in 2005, the limiting factor is weather. Moisture, both in the soil where the mycelium occurs and in the air immediately above the soil surface, is believed to be critical for morel fruiting. Both soil moisture and relative humidity are affected by the snowpack of the preceding winter, the timing and rate of snowmelt, and subsequent

rainfall and temperature patterns. Although we don't know the optimal moisture conditions for morel fruiting, we believe that both the timing and amount are important. Average or above-average snowfall and a wet spring and early summer would likely increase the chances of a productive morel season.

Influx of Pickers From the Lower 48 States and Canada

People who pick morels commercially in the Pacific Northwest States and Canada typically conduct considerable research into the location and accessibility of wildfires each year. They plan their search for morels to maximize the return on their effort. In most cases, the only reason for people to travel to Alaska to pick morels commercially would be if suitable burned areas were not available closer to their home base.

The 2004 fire season in the Lower 48 States was significantly slower than average.

The 2004 fire season in the Lower 48 States was significantly slower than average. By early September 2004, a total of only 1.3 million acres had burned in the Lower 48 States, about a third of the acres usually burned by that date (Associated Press 2004). British Columbia also had a slow year in 2004, with 553,000 acres burned by early September. However, a total of 4.32 million acres burned in the Yukon Territory in 2004, significantly more than average. Roughly 20 percent of the Yukon Territory wildfires had road access either adjacent to the burn or passing through some part of it (Milne 2004), about the same level of road accessibility as the 2004 Alaska fires.

Spring of 2005 is likely to see a migration of commercial morel pickers from the Pacific Northwest States and British Columbia at least as far north as the Yukon. Whether some people travel as far as Alaska to pick morels will depend on a variety of factors, including the total population of pickers, weather trends leading up to the season, and the anticipated market price for morels.

Acknowledgments

We thank the morel mushroom harvesters, agency personnel, business owners, and researchers who generously donated their time to speak with us about morel mushroom harvesting and supplied information for this report. We appreciate the hard work of our field technicians, Bridget Korman and Karl Olson. We also thank our reviewers Gunnar Knapp, Joachim Obst, Tom Paragi, and John Zasada. Portions of the funding for this research were provided by USDA through a grant to the School of Natural Resources and Agricultural Sciences, University of Alaska Fairbanks.

Metric Equivalents

When you know:	Multiply by:	To find:
Feet (ft)	0.305	Meters
Square feet (ft^2)	.093	Square meters
Miles (mi)	1.609	Kilometers
Square miles (mi^2)	2.59	Square kilometers
Miles per square mile (mi/mi^2)	0.621	Kilometers/square kilometers
Pounds (lb)	454	Kilograms
Acres (ac)	.405	Hectares
Pounds per acre (lb/ac)	1.121	Kilograms per hectare

References

Alaska Wildland Fire Coordination Group. 1998. Alaska Interagency Wildland Fire Management Plan. http://www.dnr.state.ak.us/forestry/pdfs/98AIFMP.pdf. (9 December 2004).

Arora, D. 1986. Mushrooms demystified: a comprehensive guide to the fleshy fungi. Berkeley, CA: Ten-Speed Press. 959 p.

Arora, D. 2001. Wild mushrooms and rural economies. In: Moore, D.; Nauta, M.M.; Evans, S.E.; Rotheroe, M., eds. Fungal conservation: issues and solutions. Cambridge, United Kingdom; New York: Cambridge University Press for the British Mycological Society: 105-110. Chapter 8.

Associated Press. 2004. Slow season tough on private firefighting crews…except in Alaska. Fairbanks Daily News-Miner. September 8; Sect. A:1.

Blatner, K.A.; Alexander, S. 1998. Recent price trends for non-timber forest products in the Pacific Northwest. Forest Products Journal. 48(10): 28-33.

Buscot, F.; Kottke, I. 1990. The association between living roots and ascocarps of *Morchella rotunda* Boudier with roots of *Picea abies* (L.) Karst. New Phytologist. 116: 425-430.

Carrier, P.; Krebs, C.J. 2002. Trophic effects of rainfall on *Clethrionomys rutilus* voles: an experimental test in a xeric boreal forest in the Yukon Territory. Canadian Journal of Zoology. 80: 821-829.

Clarke, J.N.; Angersbach, K. 2001. The federal four: change and continuity in the Bureau of Land Management, Fish and Wildlife Service, Forest Service, and National Park Service, 1970-2000. In: Davis, C., ed. Western public lands and environmental politics. Boulder, CO: Westview Press: 35–51. Chapter 3.

Dahlstrom, J.L.; Smith, J.E.; Weber, N.S. 2000. Mycorrhiza-like interaction by *Morchella* with species of the Pinaceae in pure culture. Mycorrhiza. 9: 272-279.

Duchesne, L.C.; Weber, M.G. 1993. High incidence of the edible morel *Morchella conica* in a Jack pine, *Pinus banksiana*, forest following prescribed burning. Canadian Field-Naturalist. 107: 114-116.

Harbin, M.; Volk, T.J. 1999. The relationship of *Morchella* with plant roots. [Abstract]. In: XVI International Botanical Congress. St. Louis, MO: 559.

Hervey, A.; Bistis, G.; Liong, I. 1978. Cultural studies of single ascospore isolates of *Morchella esculenta*. Mycologia. 70: 1269-1274.

Hobbie, E.A; Weber, N.S.; Trappe, J.M. 2001. Determining mycorrhizal or saprotrophic status of fungi from isotopic evidence: implications for element cycling and fungal evolution. New Phytologist.150: 601-610.

Indian and Northern Affairs Canada. 1999. Mushroom harvesting in the Yukon [Brochure]. Ottawa, ON: Minister of Indian Affairs and Northern Development.

Ipsen, B. 2004. Fire records set in 2004. Fairbanks Daily News-Miner. October 29; Sect. A:1.

Jones, A. 1983. Nauriat niginaqtuat: plants that we eat. U.S. Indian Health Service. Written pursuant to Indian Health Service Contract Number 243-79-0220. 150 p. Unpublished report. Available from the University of Alaska Anchorage library.

Jones, E.; McLain, R.; Weigand, J., eds. 2002. Nontimber forest products in the United States. Lawrence, KS: University Press of Kansas. 445 p.

Kasischke, E.S.; Rupp, T.S.; Verbyla, D.L. [In press]. Fire trends in the Alaskan boreal forest. In: Chapin, F.S., III; Oswood, M.; Van Cleve, K. [and others], eds. Alaska's changing boreal forest. Oxford University Press, New York.

Kenney, N. 1996. An overview of the Yukon morel mushroom industry. Prepared for Government of Yukon Department of Economic Development, Department of Renewable Resources. 68 p. Unpublished report. On file with: USDA Forest Service, Boreal Ecology Cooperative Research Unit, Box 756780, University of Alaska Fairbanks, Fairbanks, AK 99775.

Kruse, J. 2004. Identification of larvae on the morel. jkruse@fs.fed.us. (17 November).

Malchow, D. 1991 (27 December). Letter to Les Fortune, Northern Regional Forester. Morrell mushroom revenue and regulation opportunities. 2 p. On file with: USDA Forest Service, Boreal Ecology Cooperative Research Unit, Box 756780, University of Alaska Fairbanks, Fairbanks, AK 99775.

McFarlane, E.M.; Pilz, D.; Weber, N.S. [In press]. High-elevation gray morels and other *Morchella* species harvested as non-timber forest products in Idaho and Montana. Mycologist.

Miles, P.G.; Chang, S. 1997. Mushroom biology: concise basics and current developments. River Edge, NJ: World Scientific. 194 p.

Milne, D. 2004. Personal communication. Wildland fire prevention coordinator, Department of Energy, Mines, and Resources, Forest Management Branch, Government of Yukon, Box 2703, Whitehorse, YK, Canada Y1A 2C6.

Molina, R.; O'Dell, T.; Luoma, D. [and others]. 1993. Biology, ecology, and social aspects of wild edible mushrooms in the forests of the Pacific Northwest: a preface to managing for commercial harvest. Gen. Tech. Rep. PNW-GTR-309. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 42 p.

Moorhouse, J. 2004. Prized treat pops out of ashes. Penticton [BC] Herald. May 13; Sect A:1.

Moser, M. 1949. Über das Massenauftreten von Formen der Gattung *Morchella* auf Waldbrandflächen [On the massive occurrence of forms of the genus *Morchella* on forest-fire burn areas]. Syndowia, Annales Mycologici Ser. II, 3: 174-195.

Obst, J.; Brown, W. 2000. Feasibility of a morel mushroom harvest in the Northwest Territories. Arctic Ecology and Development (AED) Consulting, and Deton'cho Corporation. Unpublished report. Available from the University of Alaska Fairbanks library.

O'Donnell, K.; Weber, N.S.; Rehner, S. [and others]. 2003. Phylogeny and biogeography of *Morchella* [Abstract]. In: The 22nd Fungal Genetics Conference: Fungal Genetics Newsletter. 50(Suppl.): 443.

Ower, R.D.; Mills, G.L.; Malalchowski, J.A., inventors. 1986 (June 17). Neogen Corporation, assignee. Cultivation of *Morchella*. U.S. Patent 4,594,809.

Parks, C.G.; Schmitt, C.L. 1997. Wild edible mushrooms in the Blue Mountains: resource and issues. Gen. Tech. Rep. PNW-GTR-393. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 22 p.

Pilz, D.; Molina, R., eds. 1996. Managing forest ecosystems to conserve fungus diversity and sustain wild mushroom harvests. Gen. Tech. Rep. PNW-GTR-371. Portland OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 104 p.

Pilz, D.; Molina, R. 2002. Commercial harvest of edible mushrooms from the forests of the Pacific Northwest United States: issues, management, and monitoring for sustainability. Forest Ecology and Management. 155: 3-16.

Pilz, D.; Alexander, S.; Schroeder, R.F.; Smith, J.; Freed, J. [N.d.]. Alaskan nontimber forest product opportunities. Manuscript in preparation. On file with: Forest Resource Enterprises, 53613 Bobwhite Court, LaPine, OR 97739.

Pilz, D.; Weber, N.S.; Carter, M.C. [and others]. 2004. Productivity and diversity of morel mushrooms in healthy, burned and insect-damaged forests of northeastern Oregon. Forest Ecology and Management. 198: 367-386.

Roach, J. 2002. Personal communication. Transportation planner, Alaska Department of Transportation, 2301 Peger Road, Fairbanks, AK 99709.

Saskatchewan Environmental Society. [N.d]. SES fact sheet, non-timber forest products: economic development while sustaining our northern forests. http://www.environmentalsociety.ca/. (9 December 2004).

Schlosser, W.E.; Blatner, K.A. 1995. The wild edible mushroom industry of Washington, Oregon and Idaho: a 1992 survey. Journal of Forestry. 93(3): 31-36.

Schmidt, E.L. 1983. Spore germination of and carbohydrate colonization by *Morchella esculenta* at different soil temperatures. Mycologia. 75(5): 870-875.

Schnepf, C.C. 1992. Special forest products. Alternative agricultural enterprises: production, management and marketing publication series. University of Idaho, College of Agriculture, Cooperative Extension System and Agriculture Experiment Station. http://info.ag.uidaho.edu/pdf/CIS/CISO952.pdf. (9 December 2004).

Viereck, L.A. 1973. Wildfire in the taiga of Alaska. Quaternary Research. 3: 465-495.

Viereck, L.A.; Schandelmeier, L.A. 1980. Effects of fire in Alaska and adjacent Canada—a literature review. BLM-Alaska Technical Report 6. Anchorage, AK. 124 p. Unpublished report. On file with: USDA Forest Service, Boreal Ecology Cooperative Research Unit, Box 756780, University of Alaska Fairbanks, Fairbanks, AK 99775.

Volk, T.J. 1991. Understanding the morel life cycle: key to cultivation. McIlvainea. 10(1): 76-81.

Weber, N.S. 1995. A morel hunter's companion: a guide to the true and false morels. Holt, MI: Thunder Bay Press. 209 p.

Wills, R.M. 2002. An economic strategy to develop non-timber forest products and services in British Columbia. http://www.mushworld.com:1508/. (22 December 2004).

☆ U.S. GOVERNMENT PRINTING OFFICE: 2005 — 789-096 / 00023 Region No. 10

The **Forest Service** of the U.S. Department of Agriculture is dedicated to the principle of multiple use management of the Nation's forest resources for sustained yields of wood, water, forage, wildlife, and recreation. Through forestry research, cooperation with the States and private forest owners, and management of the National Forests and National Grasslands, it strives—as directed by Congress—to provide increasingly greater service to a growing Nation.

The U.S. Department of Agriculture (USDA) prohibits discrimination in all its programs and activities on the basis of race, color, national origin, gender, religion, age, disability, political beliefs, sexual orientation, or marital or family status. (Not all prohibited bases apply to all programs.) Persons with disabilities who require alternative means for communication of program information (Braille, large print, audiotape, etc.) should contact USDA's TARGET Center at (202) 720-2600 (voice and TDD).

To file a complaint of discrimination, write USDA, Director, Office of Civil Rights, Room 326-W, Whitten Building, 14th and Independence Avenue, SW, Washington, DC 20250-9410 or call (202) 720-5964 (voice and TDD). USDA is an equal opportunity provider and employer.

USDA is committed to making the information materials accessible to all USDA customers and employees

Pacific Northwest Research Station

Web site	http://www.fs.fed.us/pnw
Telephone	(503) 808-2592
Publication requests	(503) 808-2138
FAX	(503) 808-2130
E-mail	pnw_pnwpubs@fs.fed.us
Mailing address	Publications Distribution Pacific Northwest Research Station P.O. Box 3890 Portland, OR 97208-3890


NATIONAL AGRICULTURAL LIBRARY
1022688893

U.S. Department of Agriculture
Pacific Northwest Research Station
333 S.W. First Avenue
P.O. Box 3890
Portland, OR 97208-3890

Official Business
Penalty for Private Use, $300